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(54) ELECTROCHEMICAL CELLS

(71) We, LOCKHEED MISSILES AND SPACE COMPANY INC., of 1111 Lockheed Way, Sunnyvale, California 94088, United States of America, a corporation organised under the laws of the State of California, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to electrochemical cells.

United States of America Patent Specification No. 3,791,871 describes such a cell which utilizes a reactive metal anode highly reactive with an aqueous electrolyte and spaced from a cathode by an electrically insulating film which forms naturally on the anode in the presence of water. This thin film separates the cathode from the anode. The resulting reduction in the anode-cathode spacing to a thickness no greater than the thickness of this film greatly reduces the $I^2 R$ losses which would otherwise be present and results in increased power output and energy density. The anode and cathode operate in an aqueous electrolyte which supports the beneficial electrochemical reaction. The cathode may beneficially be formed of an open-mesh metallic screen contoured to contact the film over substantially the entire operating surface of the anode.

During operation of the cell, the molarity of the electrolyte increases with a resulting decrease in power output. Further, excess heat must be removed from the electrolyte which would otherwise result in a loss of efficiency. Likewise, depolarization of the cell must be accomplished by removal of hydrogen gas evolved at the cathode. Accordingly, the electrolyte is normally pumped through the cell in order to remove heat, bring in additional oxidant to maintain the desired molarity and remove hydrogen. The mechanical pumps and heat exchangers used for this purpose are cumbersome, consume power and generate noise, all of which are undesirable.

An object of the present invention is to

provide a configuration which dispenses with the necessity of mechanical pumps and heat exchangers and which by use of the products of the electrochemical reaction, is self-pumping, the pumping force being supplied by the waste heat and hydrogen gas evolved. The configuration has the further advantage of reducing non-working anode edge surfaces which would normally be exposed to the electrolyte and therefore be subject to parasitic erosion.

In accordance with the invention, there is provided an electrochemical cell comprising a vertical hollow tubular casing, a reactive anode bonded to the interior surface of said casing, said anode naturally forming on its surface a protective insulating film in the presence of water, an expandable coiled metal open-mesh screen cathode positioned within the interior of said tubular casing and contacting said insulating film over substantially all of the anode surface facing said cathode, said cathode pressing continuously against said insulating film during operation of said cell, and an aqueous electrolyte flowing through and filling the interior cavity of said hollow tubular casing, said electrolyte flow from the bottom to the top of said cell being caused solely by evolved heat and gas generated during the operation of said cell.

The circular construction of the anode does not provide any non-working exposed edges other than the small top and bottom seams at the ends of the tube and parasitic erosion is accordingly minimized. During operation, reaction of lithium with the electrolyte in the interior cavity of the casing causes the electrolyte to be heated thereby establishing a thermal gradient in the cell. This gradient and the buoyancy of the hydrogen gas evolved at the cathode creates a flow of electrolyte through the cell, with hot electrolyte containing hydrogen gas exiting from the top of the cell and fresh oxidant being drawn into the bottom of the cell.

In the accompanying drawings which illustrate a preferred embodiment of the invention:

Fig. 1 is a top view of two cells of the invention operating from a common electrolyte reservoir; and

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Fig. 2 is a edge cross-sectional view of the cells of Fig. 1.

With reference to Figs. 1 and 2, where like reference characters designate corresponding parts throughout the views, there is depicted two cells of the invention 1 and 2 operating, in this embodiment, from a common reservoir 3. Reactive metal anodes 4 are bonded, for example by metallurgical means, to the inside walls of the tubular metal casings 5. An insulating film 6 which forms naturally on anodes 4 electrically separates anodes 4 from expanding coiled metal screen cathodes 7. As the anode 4 is consumed in operation, the cathode 7 expands to maintain contact with the film 6 over substantially all the anode surface facing the cathode 7. A cathode current collector 8 is bonded to each screen cathode 7 and an anode connector 9 is bonded to the exterior of each cell casing 5.

The two cells 1 and 2 are connected to a central reservoir 3 by means of pipes 10 and 11. The upper pipes 10 are for egress of the circulating electrolyte 12 and the lower pipes 11 are for ingress of the electrolyte into the cells. To enhance rejection of heat to the environment the depicted cells and central reservoir may be immersed in a liquid bath such as water. If the liquid bath is an electrically conducting fluid, the exterior surfaces of the metal cell casings 5 are electrically insulated, for example, with an insulating epoxy paint, not shown. Naturally, there may be only one or more than two cells connected to a central reservoir instead of the two cells depicted in the drawing.

As the cells operate, the electrolyte 12 circulates down through the reservoir 3 as it cools and evolves the entrained hydrogen and enters the cells 1 and 2 by way of pipes 11. Evolved hydrogen is vented through relief valve 13. Oxidant, normally water, is admitted through inlet pipe 14 as required to keep the cells operating at the desired power level.

As discussed in the aforesaid United States of America Patent Specification No. 3,791,871 the molarity of the electrolyte is varied to control the power output of the cells. Whereas conventional batteries decline in both voltage and power during discharge reaching a point of unacceptably low voltage before the active materials are consumed, voltage and power in the cells of the invention are maintained at the desired level throughout the life of the anode. The voltage and power output per unit area of cells of the invention are primarily dependent on electrolyte concentration and temperature. The temperature is maintained relatively constant by the configuration of the cells of the invention. Accordingly control of voltage and power is accomplished by varying the molarity of the electrolyte. During operation,

the cells of the invention produce a reactive metal hydroxide at the anode which tends to reduce power output as the concentration exceeds an optimum molarity which can be readily calibrated. Accordingly, an oxidant, typically water, is added to the electrolyte to control molarity, that is, reduce the hydroxide concentration. The control function used to control power output is total cell voltage. Variations of voltage above or below the desired level are sensed by an electronic sensor which actuates a solenoid valve which in turn controls the rate of water addition through pipe 14 to the electrolyte. Excess electrolyte generated by such oxidant additions is vented through valve 13.

Anode 4 is formed of a reactive metal such as sodium or lithium which is highly reacting with and in the presence of water naturally forms on its surface a protective insulating film. Alloys and compounds of such alkali metals and other reactive metals should be equally feasible for use as the anode provided they are substantially as reactive with water as are sodium and lithium and further provided, in common with sodium and lithium, they naturally form a continuous insulating film in the presence of water. The open-mesh screen cathode is of any suitable electrically conductive material which is non-reactive with water and will permit electrochemical reduction of water during operation of the cell. Illustratively, iron and nickel are preferred materials with platinum black and nickel black providing increased efficiency at the expense of high cost and reduced durability. The minimum size of the screen is governed by the need to get electrolyte to the anode face plus the need to remove the products of reaction away from the face. The maximum screen size is governed by the desire to keep all parts of the anode face as near as possible to the cathode. Illustratively, for an anode surface measuring 5 inches by 11 inches, a metal screen with 0.003 inch metal and 0.1 inch by 0.05 inch openings has produced excellent results.

During operation, the cells of the invention produce a metal hydroxide, the particular metal being dependent on the composition of the anode. Accordingly, for ease of operation, the aqueous electrolyte is preferably the same as that produced by the reactive metal-water reaction. However, any one of a number of other aqueous solutions should be equally feasible as a starting electrolyte provided such electrolytes have the requisite film forming characteristics. When dry storage is desired the reservoir 3 may be filled with appropriate dry electrolytes such as lithium hydroxide monohydrate and the cell activated by the introduction of water into the reservoir.

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While a central reservoir is not required for single or multiple cell operation, it is considered desirable for multiple cell operation in that the reservoir contributes to maintaining electrical balance between multiple cells by providing all cells with electrolyte of equal molarity and temperature.

Illustratively, four tubular cells, 6 inches long and 1 inch in diameter, containing $\frac{1}{2}$ -inch thick lithium bonded to the inner walls of each tube for a length of $5\frac{1}{2}$ inches, were operated connected to a central reservoir containing 1.0 molar lithium hydroxide solution in LiCl for two hours at a power level of 50 watts. The temperature of the electrolyte was 28°C and the unit was operated in an aqueous media at a temperature of 25°C.

WHAT WE CLAIM IS:—

1. An electrochemical cell comprising a vertical hollow tubular casing, a reactive anode bonded to the interior surface of said casing, said anode naturally forming on its surface a protective insulating film in the presence of water, an expandable coiled

metal open-mesh screen cathode positioned within the interior of said tubular casing and contacting said insulating film over substantially all of the anode surface facing said cathode, said cathode pressing continuously against said insulating film during operation of said cell, and an aqueous electrolyte flowing through and filling the interior cavity of said hollow tubular casing, said electrolyte flow from the bottom to the top of said cell being caused solely by evolved heat and gas generated during the operation of said cell.

2. An electrochemical cell substantially as described with reference to the accompanying drawings.

3. A plurality of electrochemical cells as claimed in any preceding claim connected to a common electrolyte reservoir.

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COMPLETE SPECIFICATION

1 SHEET

*This drawing is a reproduction of
the Original on a reduced scale*

FIG. 1

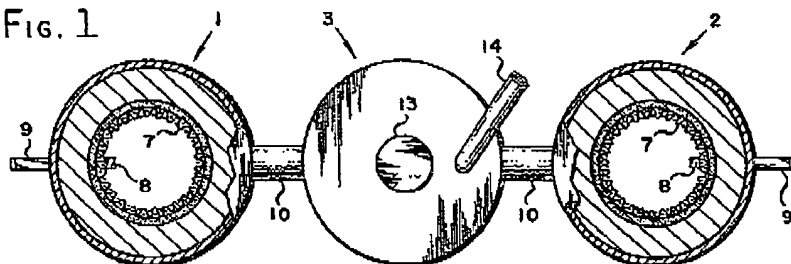
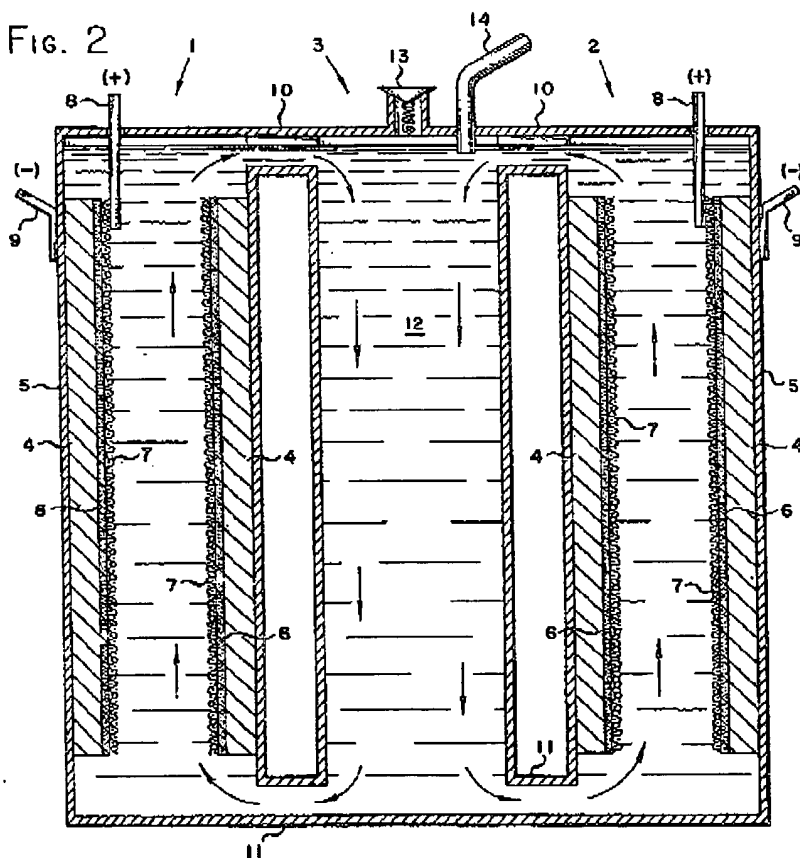


FIG. 2



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